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AIR UNIVERSITY

**NATIONAL ENERGY SECURITY
AND RELIANCE ON FOREIGN OIL**

by

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Biography

Mr. Henry D. Dall is a student at the Air War College (AWC), Maxwell Air Force Base, AL. On completion of AWC, Mr. Dall will return to Hill Air Force Base, UT, as Director, 519th Combat Sustainment Squadron, 84th Combat Sustainment Wing, Ogden Air Logistics Center. In this position he is responsible for providing a broad range of skilled resources to support acquisition and sustainment of multiple programs identified for specialized management by the Secretary of the Air Force.

Mr. Dall has 27+ years of experience in engineering, logistics management, program management, and depot maintenance support policy. He began his civilian career in 1981 as an Electronics Engineer at Hill Air Force Base, UT, working in multiple positions supporting acquisition, development, and sustainment of laboratory infrastructure systems in support of Operational Flight Program (OFP) software development. Mr. Dall established field activities, at Hill AFB, in support of depot repair assignments for the Joint Strike Fighter (JSF) and F-22 weapon systems. Mr. Dall completed a logistics career broadening assignment to the Pentagon, with responsibilities for establishing Air Force depot maintenance policy. Following this assignment, Mr. Dall transferred to the Aeronautical Systems Center, Wright-Patterson Air Force Base, F-22 System Program Office (SPO) with responsibilities to develop an F-22 sustainment transition plan. This involved moving the F-22 weapon system long-term sustainment strategy from a Contractor Logistics Support (CLS) construct to a Performance-Based Logistics (PBL) with partnerships construct. Prior to assuming his current position, Mr. Dall was Director, 519 Software Maintenance Squadron, 309 Software Maintenance Group, 309 Maintenance Wing, Hill Air Force Base, UT.

Mr. Dall enlisted in the Air Force in 1971, serving as an Intelligence Analyst and entered the Utah Air National Guard in 1974. Mr. Dall received a commission in 1984 and during much of his civilian career, served as an Intelligence Officer with the 151st Air Refueling Group, Utah Air National Guard. Mr. Dall retired in 2000 with 25 years of combined Air Force active duty and reserve service. Mr. Dall retired at the rank of Major.

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Chapter 1

National Energy Security and Reliance on Foreign Oil

End of oil is coming. Whether the United States acts now to end a reliance on foreign oil or continues this reliance, and the threat it poses to national energy security, is vital to our future. Reducing reliance on foreign oil imports is in the interest of United States national security. In a recent policy memorandum, “*American Made Energy*,” President Bush stated: “Our dependence on oil not only reduces our energy security, it leaves our economy vulnerable to outside forces.”¹ The United States must make an investment to reduce this reliance on foreign oil and continue to develop an infrastructure more reliant on renewable energy sources.

The significant increase in oil prices over the past year has served as a wake-up call to re-energize development of alternative energy sources and putting into place an infrastructure where reusable sources can provide a greater portion of the United States energy needs, with less reliance on foreign imports. Recent legislation, the *Energy Independence and Security Act of 2007*, intends to ensure national energy security through:

- Improved Vehicle Fuel Economy
- Increased Production of Biofuels
- Improved Standards for Appliances and Lighting
- Energy Savings in Buildings and Industry
- Energy Savings in Government and Public Institutions
- Accelerated Research and Development
- Carbon Capture and Sequestration
- Improved Management of Energy Policy
- International Energy Programs
- Green Jobs

- Energy Transportation and Infrastructure
- Small Business Energy Programs
- Smart Grid²

Most of this imported oil comes from stable, reliable international suppliers, but enough of the world's oil comes from unstable regions and unfriendly regimes and creates a risk of supply shocks and price spikes.³ Potential for disruption in the various countries that supply oil is great and we have seen many instances where interruption results in almost immediate shortages and price increases. As a nation which can project its power anywhere in the world, within days or hours, the United States can respond to emergencies, disasters, or conflicts. In projecting this power, the United States is often accused of responding to protect its oil interests when these emergencies, disasters, or conflicts involve a nation that is a major supplier of oil.

The United States relies on imported oil for 66 percent of its annual oil requirements. This reliance presents issues for national energy security especially when the source of these imports is considered. Of these imports, Organization of the Petroleum Exporting Countries (OPEC) member nations provides 54 percent, with Persian Gulf nations providing 21 percent of the total. Imports from three OPEC nations: Saudi Arabia, Nigeria, and Venezuela, comprise two-thirds of the OPEC oil. These countries provide 14.5 percent, 11 percent, and 11.5 percent, respectively of the total imported oil.⁴ Canada and Mexico are two other major suppliers of imported oil, providing 19 percent and 14 percent of the total, respectively.⁵ Political turmoil in Nigeria and, more recently, in Venezuela are areas where the United States should be concerned as imports could be interrupted causing shortages.

Only one week into the Obama administration, the President has signaled a need for swift and extraordinary action by sending to Congress, legislation designed to create an energy economy

intended to create millions of jobs and re-establishing United States leadership in renewable energy. The “American Recovery and Reinvestment Plan” establishes the following goals:

- Create 460,000 jobs and double capacity to generate alternative energy over the next three years
- Lay down 3000 miles of transmission lines to take energy to every corner of the country
- Save \$2 Billion per year by making federal buildings more energy efficient, and
- Save working families hundreds of dollars per year through a weatherization program.⁶

Additionally, the President issued a call to implement new standards of efficiency for cars and trucks by 2020 that increases efficiency by 40 per cent reducing our reliance on Persian Gulf oil to nearly zero.⁷

Much of the research into renewable energy resources was a result of the 1970s energy crisis and the shock of high oil prices. As prices declined, in the early-mid 1990s, much of the potential for reliable renewable energy resources was abandoned by the national government that had supported these resources.⁸ This abandonment has created a credibility gap among members of the energy industry, the larger environmental groups, and energy system installers.⁹ Current oil price increases and a realization that demand continues to increase has resulted in a significant increase in research and enactment of public laws meant to speed development and reduce United States reliance on foreign oil imports.

Renewable energy sources are available in many forms. Hydropower is the most successful form of renewable energy, but there is little opportunity for increased capacity. Other forms of renewable energy generation—wind, solar, geothermal, and biomass—have the potential to make more significant contributions in coming years. The most important barrier to increased renewable energy production remains economic; non-hydropower renewable energy generation costs are greater than other traditional energy sources.¹⁰ As noted earlier, costs involved with

these renewable energy sources has declined sharply in recent years and are now becoming competitive with non-renewable sources.

Over the past several years, we have seen oil rise to a price of over \$147 per barrel, with cost at the gas pump averaging \$4.14 per gallon.¹¹ There is no one reason for this increase, but production limitations and increasing demand, hurricanes, unrest in supplier nations, speculation, and terrorist threats have all contributed. Only recently has a reduction in demand has driven the price to nearly \$34 per barrel. The rapid collapse of oil prices due to weakening demand resulting from a growing global financial crisis has brought to question the resolve of continuing investment into renewable energy sources. Twice in the past month, the Organization of Oil Exporting Countries (OPEC) has met to establish reduced production goals in an attempt to raise oil prices. To date, these reductions have had little effect on worldwide oil prices. After falling for nearly six months, oil prices are beginning to increase slightly and forecasts indicate prices through 2009 will average in the \$43 per barrel range, and through 2010 will average in the \$54 per barrel range.¹² The world financial crisis is projected to continue through 2009, and begin easing in 2010, resulting in the increased prices through 2010. At these forecast oil prices, costs involved with installation, production, and operation of many of the renewable energy sources are less and thus remain viable options.

The following quote, taken from *A Look Back at the U.S. Department of Energy's Aquatic Species Program – Biodiesel from Algae*, articulates concerns described in 1998 relative to United States energy security:

Energy security is the number one driving force behind DOE's Biofuels Program. The United States transportation sector is at the heart of this security issue. Cheap oil prices during the 1980s and 1990s have driven foreign oil imports to all time highs. In 1996, imports reached an important milestone—imported oil consumption exceeded domestic oil consumption. DOE's Energy Information

Administration paints a dismal picture of our growing dependence on foreign oil. Consider these basic points:

- Petroleum demand is increasing, especially due to new demand from Asian markets
- New demand for oil will come primarily from the Persian Gulf.
- As long as prices for petroleum remain low, we can expect our imports to exceed 60 percent of our total consumption ten years from now.
- U.S. domestic supplies will likewise remain low as long as prices for petroleum remain low.

Not everyone shares this view of the future, or sees it as a reason for concern. The American Petroleum Institute does not see foreign imports as a matter of national security. Others have argued that the prediction of increasing Mideast oil dependence worldwide is wrong. But the concern about our foreign oil addiction is widely held by a broad range of political and commercial perspectives.

While there may be uncertainty and even contention over when and if there is a national security issue, there is one more piece to the puzzle that influences our perspective on this issue. This is the fact that, quite simply, 98 percent of the transportation sector in the U.S. relies on petroleum (mostly in the form of gasoline and diesel fuel). The implication of this indisputable observation is that even minor hiccups in the supply of oil could have crippling effects on our nation.¹³

As we enter 2009 little has changed, with the exception that oil prices have reached record highs, imports of foreign oil continue to increase, and little progress has been made in ensuring energy security for the United States or reducing our reliance on foreign oil imports.

This paper reviews current and future state of renewable energy resources, the potential of those renewable energy sources, and reviews the alternate future studies produced by the *Blue Horizons* project. As the United States reduces its reliance on foreign oil imports and increasing use of renewable energy resources, and the countries identified in the alternate future studies prepare for the eventual decline of oil production, these outcome of these alternate futures could be different if the identified countries embrace renewable energy technologies.

Blue Horizons was commissioned by AF/A8 with the Air University at Maxwell AFB serving as the Air Force “Think Tank.” *Blue Horizons* members develop studies providing “a new look at the future.”¹⁴ Specifically, the Chief of Staff asked us to “provide a common

understanding of future strategic and technological trends for Air Force leaders to make better decisions.”¹⁵

Chapter 2

Renewable Energy Sources: Technologies and Forecasts

As the United States national energy strategy evolves to address the increasing reliance on imported energy products, expanded use of renewable energy sources is an imperative. Considering the recent election and the energy strategy proposed by the Obama/Biden administration, it is important to review and discuss the most promising alternatives that serve to reduce or eliminate United States reliance on foreign energy imports. Any one of the renewable energy resources discussed will not solve our reliance on foreign oil, but together they will provide considerable relief.

Renewable Energy Sources

Renewable energy sources are sources that are inexhaustible within the time horizon of humanity, and can be subdivided into three categories: solar energy, planetary energy, and geothermal energy.¹⁶ This work focuses on renewable energy derived from solar energy. Taken at its broadest definition, *solar energy* is sometimes used to describe any phenomenon created by solar sources and captured in a form of energy, directly or indirectly—from photosynthesis to photovoltaics.¹⁷ This work uses a more conservative definition for *solar energy* as in—"direct-only solar sources, whether active, passive, thermal, or electric – that is, sources of energy that can be directly attributed to the light of the sun or the heat that sunlight generates."¹⁸ Renewable

energy sources, deriving their energy indirectly from the sun (wind energy and biomass energy), are addressed and forecasts provided.

Solar Energy

The potential for solar energy is enormous as the Earth receives 174 Petawatts (PW) of incoming solar radiation at the upper atmosphere.¹⁹ The amount of solar energy reaching the surface of the planet is so vast that in one year it is about twice as much as will ever be obtained from all of the Earth's non-renewable resources of coal, oil, natural gas, and mined uranium combined.²⁰ With this amount of energy available, the potential for harnessing this energy through renewable sources is great and developing the capabilities needed to capture and use that energy is only just beginning.

To understand direct solar energy, we must consider three methods of harnessing that energy: (1) passive and active, (2) thermal and photovoltaic, and (3) concentrating and non-concentrating.²¹ Harnessing solar energy uses one, or more, combination of these characteristics. National interests are primarily in developing and commercializing thermal and photovoltaic energies as renewable solar energy sources, and thus the following discussion relates to characteristics of these renewable energy sources.

Thermal Energy

The means of harnessing thermal energy is accomplished through an active collection method –energy is captured and stored for use in some application. Thermal energy is transferred as heat into some heat transfer liquid which is stored and circulated for use in generating electricity. Depending on the liquid used in the system and the ability to store that liquid, heat energy can be stored for several hours allowing continued energy production even when the collection system is

not illuminated by the sun, such as on a cloudy day or at nighttime. Significant power generation can be achieved from large thermal systems.

One such system, an active, concentrating solar thermal system, is *Nevada Solar One* outside Bolder City, Nevada. *Nevada Solar One* is the third largest solar power plant in the world, with a nominal capacity of 64 MW and maximum capacity of 75 MW, as of June 2007. *Nevada Solar One* uses 760 parabolic troughs, with more than 180,000 mirrors, that concentrate the sun's rays onto tubes running laterally through the troughs and containing a heat transfer fluid. The heat transfer fluid is heated to 735°F (391°C) and then exchanged to water to produce steam which drives a conventional turbine.²²

A second means of harnessing thermal energy is through an active non-concentrating thermal solar system. Active non-concentrating thermal solar systems allow direct sunlight to fall onto a surface and water is heated in a series of circulating pipes to systems such as a home hot water system or heating for a swimming pool. Non-concentrating systems are simple and inexpensive to maintain and are most often used in private home applications in many countries around the world.²³

In 2006, the United States commercial generation capacity for Solar Thermal applications stood at 0.49 billion kilowatt-hours. Projections to 2030 indicate that commercial generation capacity will grow to 2.18 billion kilowatt-hours.²⁴ Cost of energy generated using a concentrated solar thermal system is in the range of \$0.12 - \$0.17 per kWh.²⁵

Photovoltaic Energy

The means of harnessing photovoltaic energy is also accomplished through an active collection method. Sunlight striking the surface of a specially manufactured semiconductor substrate results in creation of an electrical current. Each “cell” of a photovoltaic solar system

produces only a small electrical current and voltage, thus the cells are connected in parallel, to increase the current capacity, and/or in series, to increase the voltage. The cells are packaged into “modules” or “panels” to facilitate use in a system with specific design requirements.

The solar panel is only one part of the system. A typical system consists of additional components:

Depending on the application, it is usually necessary to mount the modules on some form of support structure and then join them in parallel with cabling to form a ‘solar (PV) array’. The series-parallel arrangement of cells and modules multiplies the current and reduces the electrical resistance of the array. Auxiliary items include: (i) an inverter and step-up transformer to interface with the electrical load; (ii) batteries to store electricity until required and to smooth out fluctuations in module output and electricity demand; (iii) an electrical control system to match the power output of the array to the load profile, and to regulate the operating regime of the batteries so as to avoid excessive overcharge and discharge. All of these components are collectively termed the ‘balance of system’, BoS, and represent a significant fraction of the overall cost of a functional array.²⁶

Other than scaling the elements of the auxiliary system, addition of more solar panels, and a mechanical tracking system to ensure optimized output from the system; installation, set-up, and operation of a photovoltaic system does not significantly increase in complexity from a small system such as used in a residential application, to a large commercial system.

Two critical concerns relative to photovoltaic systems are its operating efficiency and cost. Efficiency, measured in the ability to convert sunlight into electrical energy, has steadily increased over the years to values of 18 percent to 25 percent, depending on the cell technology. As efficiency has increased, the cost has decreased from around \$15-\$20 per Watt to around \$5 per Watt in 2004.²⁷ Continuing development has led to a breakthrough as the Defense Advanced Research Projects Agency (DARPA) recently:

...demonstrated breakthrough conversion efficiency with a set of very high efficiency solar cells – over 42 percent – and is currently using this set in a proof-of-concept solar power module with an objective of 40 percent efficiency, which would be almost double that of current solar power modules. The end-of-program goal is to achieve 50 percent efficiency affordably at the module level. The

DARPA module is using a novel lateral cell design that will be optimized in spectrally split band gaps (high, medium-high and low). If successful, this could be a game changer, making solar energy cost effective.²⁸

The Air Force continues to support initiatives for renewable energy. As an example, "Solar power is the largest contributor in the Air Force's renewable energy development program. In December 2007, the Air Force commissioned the largest photovoltaic solar array in the Americas (14.2 megawatts) at Nellis Air Force Base. This supports about one fourth of the base's energy usage per day and has an estimated annual cost savings of \$1 million."²⁹

In 2006, the United States commercial generation capacity for photovoltaic applications stood at 0.01 billion kilowatt-hours. Projections to 2030 indicate that commercial generation capacity will grow to 0.96 billion kilowatt-hours.³⁰ Cost of energy generated using a photovoltaic system is in the range of \$0.21 - \$0.38 per kWh.³¹ Prospects for solar energy are:

About 2015 solar energy will boom. The industry will have perfected both significantly different photovoltaic cells and solar thermal systems that allow their commercialization at costs competitive with the grid. The photovoltaic improvements will allow substantial restructuring of the grid to a much more distributed one, one that will allow consumers to take advantage of a coming national net-metering bill proposed with such foresight in 2007 by a certain congressman from Washington State. Solar thermal plants will make a perfect team with wind by providing base load during the day, with wind at night. As low-cost solar moves into mass markets, it will stabilize process for consumers, radically reduce both pollution and strains on the grid, and create a booming export market for development applications in the third world as distributed generation becomes the standard for emerging economies. This is the gutsiest prediction that will be made in these pages.³²

Renewable energy produces through solar sources suffers from one significant shortcoming: if the sun is not shining on the generating station, no power is produced. This impact is mitigated by storing the energy produced in some medium where it can be used as needed. In a concentrating or non-concentrating solar application, several hours of energy can be stored and used when needed. In a solar cell application, batteries are typically used as the storage medium. In either case, excess energy generated that cannot be stored or used can be directed into the

power grid becoming a source of revenue for the project. An additional concern is related to the size of a system, and thus the land and/or roof requirements to support installation.

Wind Energy

In the United States, wind energy experienced record growth in 2007 and more wind capacity was installed in the last quarter of 2007 than in all of 2006. The United States has led the world for three years in a row in annual wind capacity installations with wind energy installed capacity increasing 6.5 times between 2000 and 2007 and it is the fastest growing renewable electricity technology. Along with this growth in capacity, the levelized cost of wind power, excluding Production Tax Credits, was 6 cents per kilowatt hour in 2007—a price that competes with fossil fuel-generated electricity.³³

Wind power systems use energy of the wind to turn propeller-like blades for generating electricity, charging batteries, or pumping water. Modern wind turbine systems are grouped together forming wind farms to produce electricity for utilities. Current state-of-the-art wind turbines have a generating capacity of approximately 3.5 MW, with development continuing on systems reaching 5 MW. Modern wind turbines stand up to 400+ feet tall, with blades that stretch 148 feet in length to take advantage of winds at these altitudes.³⁴

In 2006, the United States commercial generation capacity for wind applications stood at 25.78 billion kilowatt-hours. Projections to 2030 indicate that commercial generation capacity will grow to 123.2 billion kilowatt-hours.³⁵ In 2007, installed wind power capacity in the United States increased by 5,237 megawatts, a 45 percent increase over 2006, supported by a number of federal and state standards that encourage growth of renewable energy.³⁶ Cost of energy generated using a concentrated solar thermal system is in the range of \$0.05 - \$0.085 per kWh.³⁷ Prospects for wind are:

Wind is too easy. Since it is already competitive, we predict that it will become a more substantial portion of our grid by a factor of ten. The Department of Energy and the American Wind Energy Association have predicted that wind could provide 20 percent of U.S. electricity by 2030 and given trends in Europe and the rapid growth in the United States, we are inclined to believe them. Continuing marginal improvements in its technology and the increasing cost of carbon-based fuels will push wind to the first tier of choices for utilities, particularly in the next few years and earlier than solar, wave, and biomass breakthroughs are commercialized. It will be the fastest growing of the renewable in the immediate future for that reason. Wind's ultimate ceiling will depend on our ability to perfect storage and transmission technologies that will enable us to move larger quantities of wind power onto the grid in a sustained way and will markedly reduce transmission costs from the wind-fertile Midwest and Plains states to population centers elsewhere.³⁸

While the prospects for wind energy are optimistic, several issues continue to raise concern.

First, acquisition of land and access necessary to establish and operate a windmill farm, typically consisting of a hundred or more windmills, requiring tens to hundreds of acres. Second, the size of typical windmill farms concerns some communities, thus windmill farms are located in areas remote from population centers. The sheer size of a windmill farm and additionally the size of the windmill itself add to this concern as does being remote to the power grid. Third, unpredictable winds present problems. With no wind, no energy is generated. Strong winds can damage the windmill, although computerized systems with integrated laser systems are proving effective in protecting the windmill from damaging gusts – while at the same time increasing efficiency.

Finally, in the National Defense Authorization Act (NDAA) of 2006, Congress directed the Department of Defense to conduct a study on the impact of windmill farms on military readiness. Members of Congress expressed a concern that windmill farms could impact military training and readiness by affecting radar systems making them less effective. Results of the study demonstrated that wind turbines can impact the ability of radar to discriminate between an aircraft and the wind turbine. Testing further demonstrated three mitigation approaches that could be

employed to prove effective in preventing impact to the radar system being evaluated, but each situation must be evaluated on a case-by-case basis.³⁹

Biomass Energy

Biomass energy comes mainly from plant life and animal waste—wood and dung are the leading biomass source. Biomass, in the form of wood, is the original fuel used by man for centuries and remains a primary fuel for cooking and heating in many developing countries. Worldwide, biomass supplies an estimated 9 to 13 percent of all energy.⁴⁰ Biomass is defined as: “Organic non-fossil material of biological origin constituting a renewable energy source.”⁴¹

Growth of the biomass industry has primarily been driven by private sector innovation. The Federal government has begun to show greater interest in light of high oil prices and requirements for significant increases in biomass fuels in the Energy Independence and Security Act of 2007. To sustain that growth it is essential for the federal government to work in partnership with the private sector to achieve improvements across feedstocks likely to be in use over the near- and long-terms:

- First generation feedstock includes corn for ethanol and soybeans for biodiesel. These feedstocks are currently in use and their yields have been increasing.
- Second generation feedstock consists of the residue or “left-overs” from crop and forest harvests. They show much promise for near-term adoption with the development of cellulosic conversion technologies.
- Third generation feedstock are crops which require further R&D to commercialize, such as perennial grasses, fast growing trees, and algae. They are designed exclusively for fuels production and are commonly referred to as “energy crops”. They represent a key long-term component to a sustainable biofuels industry.⁴²

First generation biomass to fuel programs using corn and soybeans as the feedstock have grown from 1.4 billion gallons per year in 1998 to nearly 6.5 billion gallons in 2007. By 2015, with additional production capacity either planned or coming on line, capacity will increase to an

expected 15 billion gallons per year where production is projected to stabilize. At this point, capacity is expected to level off with second generation biofuels becoming viable and first generation biofuels will continue as the foundation for the industry.⁴³

Production of second generation and some third generation biofuels produced from cellulosic plant matter is expected to begin in 2010 and increasing production capacity will continue to 2022. By 2022, production of all forms of liquid biofuels is planned to reach 36 billion gallons per year. This goal is established in the Energy Independence and Security Act of 2007.⁴⁴

Energy produced in biomass applications provides both electrical energy and liquid fuel. In 2006, the United States commercial electric generation capacity for biomass applications (including municipal waste) stood at 24.43 billion kilowatt-hours. Projections to 2030 indicate that commercial generation capacity will grow to 102.02 billion kilowatt-hours.⁴⁵ Cost of electrical energy generated from a biomass system is in the range of \$0.04 - \$0.12 per kWh.⁴⁶ As production capacities increase, fuels generated through the biofuels program are focused to be cost competitive with fossil fuels by 2012.⁴⁷ Prospects for the future of biomass are:

Biomass will be used to power generating turbines for electricity, but the use of biofuels in transportation will dwarf its use in electrical generation. However, sustainable biomass will also be produced for electrical energy, to be cofired in traditional power plants, and gasified and burned with cellulose for use in production of biofuels and other manufacturing applications. Bio-industry will become a much larger concept than simply producing fuels for transportation as biologically based polymers replace a host of petrochemicals in manufacturing, further reducing our dependence on oil. Both low-carbon fuel standards and certification of the sustainable production of biofuels will drive the market for bioenergy, which contributes positively to reducing climate change while minimizing strain on natural systems.⁴⁸

Renewable biomass energy especially that generated in a first generation system currently competes with human and animal feed crops. Use of corn and soybean crops in production of biofuel reduces acreage necessary for production of crops necessary for human and animals and results in increased cost of food production. As second generation biomass systems become more

available, less first generation biomass resources will be needed and land can be returned to use for human and animal needs.

Much of the world population already uses second generation biomass as fuel, not in the production of fuels to replace oil, but in direct use in cooking, heating, and other applications. Concerns arise here relative to the impact on “greenhouse gasses” and carbon dioxide generated in the process of burning materials such as wood, dung, and other cellulosic materials. These concerns will continue until biomass energy projects mature and become mainstream.

Chapter 3

Algae as a Viable Alternative Energy Source

Third generation biofuels, particularly those produced from algae feedstocks, promise significant increases in production quantities over other biomass feedstocks, but additional research and development is required before algae will become a viable replacement for oil. Algae have several properties that make their use as feedstock for producing alternative fuels very attractive. Algae hold the potential of being a game changing element in solving United States reliance on foreign oil.

The United States Department of Energy funded a program, the Aquatic Species Program (ASP) from 1978 to 1996, with a purpose of developing renewable fuels from algae. This program focused on production of biodiesel from algae grown in open ponds, utilizing waste carbon dioxide from coal fired plants.⁴⁹ Tremendous advances were made over the period of the program, but in the end, projections were that costs to produce biodiesel from algae would be two times higher than current diesel fuel costs (based on oil at a per barrel cost of approximately \$20).⁵⁰

The ASP was the source of most of research into use of algae as a feedstock for biodiesel. The ASP developed a catalog of nearly 300 algae species that demonstrated promising characteristics for producing the lipids, or natural oils, necessary for conversion into biodiesel. The focus of the ASP was to identify the “lipid trigger,” in the various algae species, that with the

organism under environmental stress would flip the switch and turn on production of these natural oils.⁵¹ The trick is to determine the level of stress necessary to maximize oil production in the cell without all cellular growth ceasing. With tens of thousands of algae species, on-going research continues to identify species which may produce more and better oils for conversion.

Algae have several characteristics offering the potential of very large yields per acre and are non-competitive with the production of food crops. Algae use solar energy to combine water with carbon dioxide to create biomass. The algae form best suited for oils are microalgae, microscopic photosynthetic organisms. Microalgae grow well in marine and freshwater environments.⁵² Ponds for growing algae can be developed on land that is unsuitable for other uses and microalgae thrive in brackish water, waste water, and about 90 percent of the water used in the process can be reused. Carbon dioxide is injected into the ponds and the algae absorb about 90 percent of the carbon dioxide in the process of producing oils, making algae well suited to cleaning carbon dioxide from the atmosphere.⁵³ As a byproduct of burning fossil fuels, carbon dioxide is a major contributor to global warming resulting in a positive impact on carbon dioxide in the atmosphere.

DARPA has issued a Broad Agency Announcement, BAA 08-07, entitled Biofuels – Cellulosic and Algal Feedstocks. The purpose of this project is to develop alternatives to petroleum-derived JP-8 from agricultural and aquacultural feedstocks.⁵⁴ The Phase 1 objective is the demonstration of algae triglyceride production at a projected cost of \$2/gal. The Phase 2 objective is the demonstration of algae triglyceride production at a demonstrated cost of \$1/gal.⁵⁵ Research is ongoing with numerous commercial companies and universities participating in the project.

A project underway in Texas may revolutionize production of oils from algae feedstocks. The companies involved in the project, Valcent Products and a Canadian alternative energy

company Global Green Solutions, use a closed, vertical system, growing the algae in long rows of moving plastic bags. The companies have invested about \$5 million in the facility. Glen Kertz, president and CEO of Valcent, said he can produce about 100,000 gallons of algae oil a year per acre, compared to about 30 gallons per acre from corn; 50 gallons from soybeans. Unlike open ponds used in previous algae production projects, growing algae in a vertical system, “you can get a lot more surface area to expose cells to the sunlight. It keeps the algae hanging in the sunlight just long enough to pick up the solar energy they need to produce, to go through photosynthesis,” he said.⁵⁶

Production of oil from algae feedstocks is a proven technology. The problem is one of economics – improving processes and reducing the cost of production to make the oil competitive with current petroleum-based oils. Continuing research in the DAPRA biofuels program may produce cost effective biofuels of several thousand gallons per acre per year, but if the Valcent system lives up to its claims, it could be a breakthrough in reducing reliance on imported oil. In any case, carbon dioxide absorbed by the algae in the process can mitigate global warming due to burning fossil fuels.

Chapter 4

Alternative Energy Sources and Alternate Futures

In order to maintain oil production output at present levels, new sources of oil equivalent to the output of six Saudi Arabias must be found between now and 2030.⁵⁷ As current oil producing fields are depleted, this investment is required to continue the demand for oil. The International Energy Agency (IEA) predicts that world energy demand will grow by 1.6 percent annually between 2006 and 2030 with a total increase of 45 percent.⁵⁸ Considering this predicted growth, countries studied in the alternate futures are prepared to develop alternative energy sources to offset their fossil fuel needs.

At current rates of use, world supplies of petroleum, natural gas, and coal are projected to be exhausted in 45, 61, and 230 years, respectively.⁵⁹ Projected increases in demand could exhaust these supplies sooner, but the potential of renewable energy sources may mitigate that eventuality. Stated another way, these supplies of energy will eventually be exhausted, but renewable energy sources have the potential to extend their availability. One assumption relating to renewable energy sources is that any development in renewable technologies by one country/company would be available to any other as most are commercially available technologies.

For the 2008 academic year, *Blue Horizons* conducted extensive research and developed four alternate future case studies. These studies were not designed to forecast a specific future, but rather designed to help the reader better understand the magnitude and shape of a rapidly world.

The nations involved in these studies may be our friend or foe. But whatever they do become, the United States must be ready to engage them as a fellow member of the international system.⁶⁰

Resurgent Russia

The “Resurgent Russia” alternate future study poses a future where Russian influence continues to grow and addressed the potential direction Russia will take over the next twenty years. Oil and gas production figures prominently in Russia’s position in the international scene. The potential for positive economic impact on the Russian economy is a major consideration in this alternate future.⁶¹

The Energy Information Administration, reports: “Russia holds the world’s largest natural gas reserves, the second largest coal reserves, and the eighth largest oil reserves. Russia holds proven reserves of 60 Billion barrels petroleum, 1,680 trillion cubic feet natural gas, and 173 Billion short tons coal. Russia is also the world’s largest exporter of natural gas, the second largest oil exporter and the third largest energy consumer.”⁶² At current depletion rates, Russian reserves of petroleum, natural gas, and coal are projected to last until approximately 2025, 2086, and approximately 2548, respectively.⁶³

The Russian economy is very dependent on oil and natural gas exports. Russia exports about 70 percent of the oil it produces. In 1998, when oil prices plunged, Russia experienced a significant economic failure. Increases of the last several years have enabled Russia to expand economically primarily a result of oil exports. This has provided Russia an opportunity to begin reestablishing its position in the global community.

As the world financial crisis was beginning to show its impact in the United States, Russia’s position is beginning to falter. With the August invasion into Georgia, Russia began to lose

significant foreign investment. Immediately after the invasion, nearly \$63 billion in foreign investment was pulled out of Russia. Add to this the deepening world financial crisis and the combination of loss, by Oct 2008, of nearly 80 per cent of the value of the Russian stock market and the financial impact of the dramatic drop in oil prices to the Russian economy will continue to accelerate as with the United States.⁶⁴

Russia has demonstrated a willingness to use oil as a weapon. In 2006, and in late-2008, Russia reduced gas flows through the pipeline system for the Ukraine and Europe. In doing so:

The Kremlin has shown it cannot be counted upon as a reliable source of energy and western markets should see this as an opportunity to take a long, thoughtful look at energy security and re-evaluate the benefits of developing renewable energy technologies.

The move, widely seen as a form of protest against Ukraine's increasingly western ways, resulted in diminished gas supplies across Europe and met condemnation by European leaders. The U.S. State Department expressed its concern saying the move "creates insecurity in the energy sector in the region and raises serious questions about the use of energy to exert political pressure."

Russia's actions, combined with continued insecurity in the Middle East, Venezuela, and Nigeria mean that the energy concerns for United States and Western Europe are not diminishing. While pursuing new oil and gas fields is an option, it would be prudent for governments to focus on renewable energy sources and technologies.

In recent years, high energy prices have provided impetus for the innovation in the development of solar, fuel cell, tidal, geothermal, wind, biomass, and other technologies that can help reduce dependence on energy from politically and socially questionable sources. These development efforts become all the more important now that Russia cannot be considered an energy supplier of last resort.⁶⁵

This willingness to use oil as a weapon – to hold nations in the region hostage – has an impact on regional stability. United States alliances with European nations, in particular with former Soviet satellite nations, place national interests at risk in these situations.

Into the future, as Russian oil supplies become depleted, development of alternative energy sources must occur for Russia to remain a viable power. Development of renewable energy

projects in Russia is hindered by a lack of legislation, low electric and heat tariffs, low public demand, and lack of investment capital. Nevertheless, the renewable energy potential qualifies Russia as a leading candidate for development.⁶⁶

Discussing the potential for renewable energy sources in Russia, the country profile indicates:

Russia is unique due to its unified power system that connects 70 localized energy systems and allows the transfer of power across the country. This is a unique situation that could allow the siting of renewable energy projects in some remote locations with access to transmission facilities which can deliver power to more densely populated areas. The overwhelming size of Russia also implies a strong development potential for all renewable energy resources.

Russia has excellent potential for **wind** power generation. An attempt to utilize just 25 percent of its total potential would yield some 175,000 MW of power. The highest wind energy potential is concentrated along seacoasts, in the vast territories of steppes and in the mountains.

Solar potential is reasonable despite the country's location in the northern latitudes. The highest solar potential is in the southern regions.

The overall technical potential of **biomass** is estimated as 35 million toe, which, if converted to electrical power, could generate nearly 15,000 MWe. This includes sewage sludge, cattle manure, and lumber waste. With the reconstruction of pulp and paper plants, the use of wood waste is also becoming more prevalent.⁶⁷

Russia's extensive stores of petroleum, natural gas, and coal, and the fact that it exports a significant amount of these resources leaves Russia with a position that it does not need to develop and field renewable energy sources. Russia has limited wind, solar, and biofuel projects in progress, but these provide an insignificant amount of renewable energy. Environmental impacts of oil, natural gas, and coal production/use will likely be the factor that forces Russia to move to renewable energy sources.

Peer China

The “peer China” alternate future study poses a future where economic growth of China continues as current well into the future and their economy comes to parity with that of the United

States. The potential for this alternate future to come to be is quite reasonable to expect. China's gross domestic product (GDP) has grown at an annual rate of 9.9 percent, per year, since 1978. If this growth continues, as expected, China's international influence could easily exceed that of the United States.⁶⁸

The worldwide financial crisis has impacted China's economy just as in other nations. This significant slowdown is evidenced by the closing of numerous factories and businesses and loss of millions of jobs. A second impact is the loss of economic growth because of this slowdown. Considering the economic slowdown is expected to continue through 2009, expect China's economic growth to be stalled until a recovery begins. Despite this slowdown, China continues to establish strategic alliances throughout the region, especially in Africa.

Currently, China imports nearly 50 percent of its oil, with projected increases to almost 75 percent of its total oil consumption by 2030, according to the International Energy Agency (IEA).⁶⁹ At a growth rate of 1.6 percent in annual world oil consumption, China is expected to account for 30 percent of the increase in world energy demand by 2030.⁷⁰ With 16 billion barrels of proven oil reserves, these reserves are projected to last 15 years, at current use rates. Thus China will continue to require imported oil for its economic growth. And, as much of the growth in China's consumption is related to its economic growth, China will require reliable sources of energy to continue that growth.

In 2005, China passed legislation for renewable energy. This legislation calls for 10 percent of China's energy needs to come from renewable energy sources by 2020. In that same year, China's investment in renewable energy was US\$6 Billion.⁷¹ The Chinese government projects that renewable energy will account for 16 percent of total energy supply by 2020, well ahead of the legislative requirement. In achieving that amount of renewable energy use, wind power and

biomass energy are anticipated to contribute 30 million kW each, and solar energy 1.8 million kW by 2020.⁷²

As a review of renewable energy sources, the following is provided to indicate the scope of wind, solar, and biomass projects in China:

Wind: The biggest surprise is China, which was barely in the wind business three years ago but which in 2007 trailed only the United States and Spain in wind installations and was fifth in total installed capacity. An estimated 3,449 megawatts of wind turbines were added in 2007, bringing China's provisional total to 6,050 megawatts and already exceeding the government's target for 2010. (An estimated one fourth of this capacity is still not connected to the grid, however, due to planning problems.) Another 4,000 megawatts are expected to be added in 2008 and, based on current growth rates, the Chinese Renewable Energy Industry Association predicts that China's wind capacity could reach 50,000 megawatts by 2015.⁷³

Solar: China climbed rapidly to become the second largest cell-producing nation after Japan, manufacturing about 820 megawatts of PVs and accounting for 22 percent of global production. But annual production capacity reached almost 1,590 megawatts by the end of the year, well ahead of any other country (though still 9 percent below all of Europe). Despite these impressive numbers, the Chinese market for PVs remains small, and much of the 20 megawatts of new capacity installed in 2007 was for remote off-grid applications.⁷⁴

Biofuels: Other renewable fuels policies enacted in 2007 include China's annual production targets of 13 billion liters of ethanol and 2.3 billion liters of biodiesel by 2020. Last year the U.N. Food and Agriculture Organization (FAO) reported that biofuel demand has played a key role in driving 8 percent of food price inflation in China. While climbing biofuel production and demand represents just one influential factor in this trend, the International Monetary Fund and other multilateral agencies report that using food to produce biofuels will continue to strain already scarce water and arable land resources.⁷⁵

China's energy policies are beginning to have an impact. As recently reported by the World Resources Institute:

After years of very rapid growth, China's energy consumption and greenhouse gas emissions now look to be slowing sharply. One major factor: China's energy efficiency and renewable energy policies—now in their third year—have begun to make a real impact at the provincial and local levels.

Electricity demand in October was down 4 percent over the same month a year ago, the first such decline in almost seven years. Details of a stimulus package

have yet to be released, but it includes 12 percent for direct energy efficiency and environmental improvements. New, more flexible and sophisticated grid infrastructure is vital to increasing the efficient use of both traditional fuels and renewable energy sources.

From the perspective of climate change and other environmental issues, it is encouraging to see that a cleaner, more efficient development approach continues to be a priority within China's overall industrial and employment goals—even in the face of an economic slowdown.

With both the U.S. and China looking to use clean energy investments to reinvigorate their economies—and with China's slower emissions growth—we have a unique opportunity to make progress on our shared interests in resolving climate change and creating healthier, more sustainable economies.⁷⁶

Chinese energy policies are mitigating oil consumption requirements and may slow additional import requirements. As renewable energy technologies improve and additional efficiencies are achieved, expect China to continue progress in developing and implementing additional renewable projects.

Failed State

The “failed state” alternate future study explores the effect of oil supplies being depleted, corrupt leadership, and failed policies leading to a breakdown in the ability of the government to function and provide services to the populace. Nigeria has a long history of violence and this continues today. The potential for the state to fail, potentially in a method similar to that posed in the study, is a possibility, but we consider efforts of the current time and possibility that change will not be so dramatic due to oil supplies being depleted without current planning to mitigate the impacts.⁷⁷

Nigeria is positioned to be one of the highest earning oil-producing countries in a pack of 10 within the sub-Saharan region during the period 2006-2030. Between them, Nigeria and Angola will account for 86 percent of \$4.1 trillion cumulative revenues of these 10 countries over 2006-2030.⁷⁸ Energy exports from sub-Saharan Africa will increase significantly as the region opts to

maximize foreign currency earnings rather than attend to domestic fuel needs, the International Energy Agency said.⁷⁹

Given the potential for this infusion of funds into the area, the Nigerian government has an opportunity to change the outcome of the future. With proven reserves of 36.3 Billion barrels,⁸⁰ Nigeria currently provides about 11 percent of the oil imported into the United States. As the United States intends to increase its imports from Nigeria to about 25 percent, by 2015, it is an important consideration to ensure that the region remains stable. As an additional consideration, Nigeria also holds 3 percent of the world's reserves of natural gas at 184 trillion cubic feet.

Under several on-going United Nations Development Programmes, Nigeria has embarked on a path toward resolving several of its basic human development problems. The goals addressed in these programs relate to resolution of environmental issues, governance and human rights, HIV/AIDS, and developing partnerships to ensure poverty reduction.⁸¹ Under these programs, the nation is stabilizing. Inflation has been reduced to single digit, economic growth has averaged 6 percent (2004-2007), and reserves have grown to \$51 Billion. Additionally, the country has made progress in procurement reform and fiscal responsibility. There are still significant challenges, but economic trends are the best in a generation.⁸²

Nigeria recently announced a program for developing renewable energy sources and establishing goals of implementing a renewable energy system by 2025.

The official launch of the Nigerian Renewable Energy Master Plan yesterday [26 January 2007] was a monumental step in developing renewable energy sources in Nigeria. This is a step towards an employed, economically prosperous and stable Nigeria. A Nigeria powered by energy from inexhaustible sources, allowing not only us, but our grandchildren's grandchildren to share in this vision.

Renewable energy technologies that utilize energy from small scale hydro, wind, solar, geothermal, biomass, biogas, and biofuels take advantage of Nigeria's abundant natural resources. Nigeria will have diverse, dependable energy sources and be able to strategically benefit from our oil resources.

Renewable energy is part of the solution to conserving far more than just oil. It will not only conserve forests, contribute to cleaner water and air and an overall better environment for Nigerians to live in. Renewable energy also has the potential to contribute to a stronger economy.

The Renewable Energy Master Plan (REMP) commits Nigeria to ambitious but achievable commitments for the development of all major renewable energy resources. It includes short, medium and long term targets, planned activities and milestones and strategies for implementation. Successful implementation will result in the installation of 2,945 MW of wind, solar PV, solar thermal, small hydro and biomass by 2025 – roughly equivalent the entire grid capacity used in Nigeria today.⁸³

Nigeria has several strong plans and means in place to implement reform to ensure stability of the country. Economic and financial reforms are underway to improve a system hampered by corruption and the country recently had its first change of civilian government without major problems. It will be several years before improvements planned in these plans will be seen, but small steps are being taken that are showing a more stable Nigeria is taking shape.

Future Insurgency

The insurgency study forecasts one plausible future in a particular state, while at the same time being designed to help the reader better appreciate future insurgencies in general. It illuminates military capabilities that may be available to insurgents in any scenario, and also serves as an illustrative case of potential 2030 conflict scenarios that might arise due to the continued virulence of radical Islam. Whether a future insurgency occurs in Saudi Arabia, or some other land – whether it is born of radical Islam or some other ideology – as an Air Force, as a nation, and as a member of the international system must be ready to counter the capabilities of future enemies.⁸⁴

The “future insurgency” scenario poses a Saudi Arabia where oil production has declined to a point that the economy is now failing. Unemployment is significantly high and discontent is growing among the populace, especially in the under 25 age group, which now comprises nearly

50 percent of the population. Many in this population group are uneducated in the skills needed for the changing world of no oil. Saudi officials should consider the impact of their available workforce and plan for changing times. In this scenario, the elements making up the insurgency may have the full range of weapons and technologies available to United States forces.⁸⁵ While this may be a plausible future, Saudi Arabia can take actions to prepare for this eventuality.

Many ask why Saudi Arabia would be interested in alternative energy sources. Consider that Saudi Arabia holds the largest reserves of oil. At 264 Billion barrels, this is approximately 20 percent of the world's reserve. In addition to oil reserves, Saudi Arabia holds the fourth largest reserve of natural gas, at 4.1 percent or 253 trillion cubic feet. As consumption continues to increase and supplies dwindle, Saudi Arabia is building a plan for the future.

Saudi Arabia has participated in considerable research and development relating to renewable energy sources, but recognizes the need for additional work in this area as stated in the work below for wind and solar applications:

The power in the earth's wind and in the solar radiation, which reaches the earth, is sufficient to make significant as well as strategic contributions to the Kingdom energy supply. Applications of solar energy in Saudi Arabia have been growing since 1960. However, effective utilization of solar energy in Saudi Arabia has not yet made reasonable progress mainly due to several obstacles. But, valuable lessons have been learned and a wealth of experience has been gained from the Kingdom experience. The technical and economic feasibility of wind energy utilization in the Kingdom has not yet fully explored. Several studies were conducted to assess the potential of wind energy in the Kingdom of Saudi Arabia. The wind map of Saudi Arabia indicates that the Kingdom is characterized by the existence of two vast windy regions along the Arabian Gulf and the Red Sea coastal areas. The mean annual wind speed in these two windy regions exceeds 9 knots (16.7 kmph) and ranges from about 14 to 22 kmph and 16 to 19 kmph over the Arabian Gulf and Red Sea coastal areas, respectively.

It is a relatively rich and rapidly developing country and so demand for electricity is growing on average at around 5 percent annually. Over the next 25 years, it is estimated that US\$117 billion will be invested in the country's power sector. The state power grid system has supplied electricity to approximately 80 percent of the population living in the state capitals and industrial centers. It is highly uneconomical to extend the electrical power grid system into the sparsely

populated regions of the Kingdom. Hence there are many small remote communities that need an independent source of electrical energy. These locations represent a significant potential for renewable energy applications. The importance of using renewable energy in Saudi Arabia will not only be confined to meeting the demands of remote sites, but can also contribute to the national grid, helping to meet the peak-load demand during the summer months.

Even though Saudi Arabia is a leading oil producer, it is keenly interested in taking an active part in the development of new technologies for exploiting and utilizing renewable sources of energy. The most natural renewable energy sources which are freely available are wind and solar. The power in the earth's wind and in the solar radiation, which reaches the earth, is sufficient to make significant as well as strategic contributions to the Kingdom energy supply.⁸⁶

In addition, work has begun on development and fielding applications for biodiesel:

In the traditional markets for biodiesel, like the U.S., the renewable fuel's greatest selling point is that it's a domestically produced clean fuel. But who says oil-rich nations like Saudi Arabia can't also take part in developing cleaner fuels? It might be one of the last places you would expect to find any sort of renewable energy investment but a British company has just struck a deal with the Middle-Eastern nation for the large-scale, commercial production of biodiesel.

The UK-based D1 Oils is creating D1 Oils Arabia Limited with Jazeera for Modern Technology. D1 Oils Arabia will be a 50/50 joint venture and will manage the plantation of jatropha trees, which D1 Oils uses as feedstock to produce renewable biodiesel. Biodiesel can be made from other sources as well like soybeans, the predominant feedstock in the U.S.

The formation of D1 Oils Arabia is expected not only to provide Saudi based customers with innovative alternative renewable fuel solutions, but also help stem desertification and reclaim land by the planting of jatropha on marginalized land. As jatropha is a non-edible crop, D1 Oils is able to irrigate the plantations with wastewater that otherwise would have been difficult to dispose of.

The commissioning of the first D1 20 refinery in Saudi Arabia is expected as soon as the plantations come on stream, which is projected to be in the second half of 2006. More refineries will be necessary as the jatropha production increases.⁸⁷

Saudi Arabian leadership is planning for the eventual decline in oil production and as alternative energy sources develop, jobs will be created as a result of that development and youth potentially dissatisfied with the future prospects will have an opportunity to help the Kingdom continue as a leader in the region. Wind, solar, and biomass applications are all viable

alternatives to oil and Saudi Arabia is well situated in the region to capitalize on all of these alternatives.

Chapter 5

Conclusion

Over the course of the past several years, driven by many reasons—increased demands in developing and established nations, natural disasters, production limitations, and speculation in world oil markets—the price of oil has risen to record highs. These record highs are now followed by a steep decline; the result of a global financial crisis, a corresponding reduction in demand, restoration of production capabilities, and possibly a realization by oil producing nations that: “...the era of cheap oil is over. The ever worsening financial crisis could possibly bring economic recession which reduces oil demand and leads to falling prices. Henceforth, the energy price in the next two years will experience great volatility; however, considering the fundamental factors, the era of cheap oil is over.”⁸⁸ This statement from the International Energy Agency (IEA) 2008 World Energy Outlook (WEO) provides insight into the continuing problem facing the world as oil supplies continue to decline.

New policies and programs, building on policies of the past, being established by the Obama administration are significant in moving forward with alternative energy sources and reducing United States reliance on foreign oil. The goal of doubling the amount of energy produced by alternative sources in three years, considering it has taken nearly thirty years to get to this point today, is very aggressive, but achievable.

The potential to replace fossil fuels with clean, renewable energy sources is an imperative necessary to ensure United States national energy security. In the renewable energy arena, several contenders stand ready to replace oil as a future source of energy. Solar, wind, and biomass; as alternatives to fossil fuels provide clean, reliable energy, that together with other forms of energy promise to lessen United States reliance on imported oil, and ensure national energy security for the United States.

Individually these forms of renewable energy—solar, wind, and biomass—show great promise, but together they will change what we know about supplying energy for our needs well into the future. Renewable energy from solar applications is a proven technology that is set to boom in the coming years. As this technology matures and becomes more available for use, its price continues to drop and will become competitive with other forms of energy. Installation of wind generating capacity continues to increase at a significant rate and has become competitive with energy produced by fossil fuel. Biofuels are maturing and becoming mainstream. First generation biofuels are mature while second generation and some third generation biofuels are anticipated to become viable by 2010. On-going biofuel development shows promise and expectations are that the products will be cost effective and competitive with oil based fuels. Algal based biofuels may become a significant contributor to reducing greenhouse gas emissions.

The recent decline in oil prices, resulting primarily from the worldwide economic downturn, has placed a damper on the move to accelerate development and implementation of alternative energy projects. Many analysts believe this decline in the price of oil is only temporary and the rebound will be to a point even higher. The United States cannot allow this temporary decline to delay continued research and development of alternative, renewable energy sources. The end of oil is coming and the United States – the world – must be prepared for it.

Bibliography

“The Pickins Plan.” <http://www.pickinsplan.com/theplan> (accessed 29 Nov 2008).

Biomass Research and Development Board. *National Biofuels Action Plan*. Washington DC: Government Printing Office, 2008.

Bradford, Travis. *Solar Revolution: The Economic Transformation of the Global Energy Industry*. Cambridge, MA: The MIT Press, 2006.

Butler, Rhett A. *Russia’s Folly: An Opportunity for Renewable Energy?*, 3 January 2006. <http://news.mongabay.com/2006/0103-energy.html>, (accessed 30 November 2008).

Cardoso, James L., Glenn L. Graham, Paul J. Moscarelli, Mr. David L. Pope, Dirk D. Smith. *Future Insurgency: COIN and the USAF in 2030*. Air University, May 2008.

CREN NEWS AND EVENTS. *Nigeria’s Renewable Energy Master Plan Launched*. <http://renewablenigeria.org/news.php?newsviewer=0000000021> (accessed 30 November 2008).

Defense Advanced Research Projects Agency (DARPA). *Broad Agency Announcement (BAA) 08-07, Biofuels – Cellulosic and Algal Feedstocks*. <https://www.fbo.gov/utils/view?id=43b32a888ae3a0640e22bc4dfe31b387> (accessed 30 November 2008).

Dell, R. M., and D. A. J. Rand. *Clean Energy*. Cambridge, UK: The Royal Society of Chemistry, 2004.

Department of Defense. *Report to Congress on Energy Security Initiatives, DoD Energy Security Task Force OUSD(AT&L)*. Washington DC: Office of the Under Secretary of Defense (Acquisition, Technology, and Logistics), October 2008.

Department of Energy, Energy Info Administration. *2007 U.S. Imports by Country of Origin*. http://tonto.eia.doe.gov/dnav/pet/pet_move_impcus_a2_nus_epc0_im0_mbblpd_a.htm (accessed 15 December 2008).

Department of Energy, Energy Information Administration. *Motor Gasoline Retail Prices, U.S. City Averages, Monthly, 1973–Current*. http://tonto.eia.doe.gov/merquery/mer_data.asp?table=T09.04 (accessed 26 January 2009).

Department of Energy, Energy Information Administration. *Short-Term Energy Outlook, January 13, 2009 Release*. <http://www.eia.doe.gov/emeu/steo/pub/jan09.pdf> (accessed 26 January 2009).

Department of Energy. *Annual Energy Outlook 2008*. Washington DC: Government Printing Office, June 2008.

Department of Energy. *International Energy Outlook 2008*. Washington DC: Government Printing Office, September 2008.

Department of Energy. *Renewable Energy Data Book*. Washington DC: Government Printing Office, September 2008.

Department of Energy. *Russia: Background*. <http://www.eia.doe.gov/emeu/cabs/Russia/Background.html> (accessed 13 December 2008).

Department of Energy. *U.S. Ethanol Industry: The Next Inflection Point.* Washington DC: Government Printing Office, August 2008.

Energy Independence and Security Act of 2007. Public Law 110-140. 110th Congress, 1st session, 19 December 2007).

Exergy Flow Chart. http://gcep.stanford.edu/pdfs/GCEP_Exergy_Poster_web.pdf (accessed 8 November 2008).

Geis John P. II, Scott E. Caine, Edwin F. Donaldson, Blaine D. Holt, Ralph A. Sandfry. *Discord or “Harmonious Society”? China in 2030.* Air University, July 2008.

Global Energy Industry Outlook. <http://www.energybusinessreports.com> (accessed 9 December 2008).

Hailes, Theodore C., Ronald Buckley, David Blanks, Mark Butler, Phillip Preen, Michael Tarlton. *Resurgent Russia in 2030: Challenge for the USAF.* Air University, July 2008.

Houchin, Dr. Roy F., John R. Carter, Jr., Christopher J. Kinnan, Daniel B. Gordon, Mark D. DeLong, Douglas W. Jaquish, Robert S. McAllum. *Cascading Failure in 2030: Nigeria – A Case Study.* Air University, May 2008.

Inslee, Jay and Bracken Hendricks. *Apollo’s Fire.* Washington, DC: Island Press, 2008.

International Energy Agency. *World Energy Outlook 2008*, http://www.worldenergyoutlook.org/docs/weo2008/WEO2008_es_english.pdf (accessed 13 December 2008).

International Energy Agency. *World Energy Outlook 2008.* <http://www.worldenergyoutlook.org/quotes.asp> (accessed 5 December 2008).

Memorandum of Agreement entitled “Strategic Studies (Blue Horizons) Special Interest Item.” Signed by General John D. W. Corley, Vice Chief of Staff of the U.S. Air Force. 17 May 2006.

Monfort, Joe. *Worldwatch Institute: Despite Obstacles, Biofuels Continue Surge*, 23 April 2008. <http://www.worldwatch.org/node/5450> (accessed 13 December 2008).

National Energy Policy. *Report of the National Energy Policy Development Group.* Washington, DC: Government Printing Office, May 2001.

Nevada Solar One. http://en.wikipedia.org/wiki/Nevada_Solar_One (accessed 8 November 2008).

Obama, Barack H., Presidential Remarks, January 26, 2009.

Office of the Director of Defense Research and Engineering, *Report to the Congressional Defense Committee: The Effect of Windmill Farms on Military Readiness*, (2006).

Partners in Development: Annual Report 2007, United Nations Development Programme (UNDP). http://web.ng.undp.org/documents/AnnualReport_2007.pdf (accessed 13 December 2008).

President, Policy Memorandum. “American Made Energy.” 18 June 2008. <http://www.whitehouse.gov/infocus/energy/energy-policy-memo.pdf> (accessed 25 November 2008).

Quaschning, Volker. *Understanding Renewable Energy Systems.* London: Earthscan, 2005.

RenewableEnergyWorld.com. *Saudi Arabian Plantations to Produce Biodiesel*, 17 February 2005. <http://www.renewableenergyworld.com/rea/news/story?id=22624> (accessed 30 November 2008).

Renewables Energy Initiative. *Russia: Country Profile.* <http://www.ebrdrenewables.com/site/renew/countries/Russia/default.aspx> (accessed 30 November 2008).

Said, S. A. M., I. M. El-Amin, and A.M. Al-Shehri. *Renewable Energy Potentials in Saudi Arabia.* King Fahd University of Petroleum & Minerals Dhahran Saudi Arabia.

<http://webfea-lbfea.aub.edu.lb/fea/research/erg/RCW/Renewable%20Energy%20Potentials%20in%20Saudi%20Arabia.pdf> (accessed 14 December 2008).

Sawin, Janet L. *Worldwatch Institute: Another Sunny Year for Solar Power*, 8 May 2008. <http://www.worldwatch.org/node/5449> (accessed 13 December 2008).

Sawin, Janet L. *Worldwatch Institute: Wind Power Continues Rapid Rise*, 9 April 2008. <http://www.worldwatch.org/node/5448> (accessed 13 December 2008).

Sheehan, John, Terri Dunahay, John Benemann, Paul Roessler. *A Look Back at the U.S. Department of Energy's Aquatic Species Program – Biodiesel from Algae*. Golden, CO: NREL, July 1998.

Smil, Vaclav. *General Energetics: Energy in the Biosphere and Civilization*. Hoboken, NJ: Wiley, 1991. http://en.wikipedia.org/wiki/Solar_power (accessed 8 November 2008).

Stratfor Global Intelligence. *The Financial Crisis in Russia*, 28 October 2008, http://www.stratfor.com/analysis/20081024_financial_crisis_russia (accessed 30 January 2009).

Turkenburg, Wim C., ed. “Renewable Energy Technology,” in *World Energy Assessment: Energy and the Challenge of Sustainability*. New York: United Nations Development Program [UNDP], 2000, <http://www.undp.org/seed/eap/activities/wea/index.html> (accessed 12 November 2008).

United Nations Development Programme Document. <http://web.ng.undp.org/> (accessed 5 December 2008).

Walton, Marsha. *Algae: “The Ultimate in Renewable Energy*,” CNN.com. <http://www.cnn.com/2008/TECH/science/04/01/algae.oil/index.html> (accessed 29 November 2008).

World Resources Institute. *A ‘green lining’ in China’s economic stimulus plan*, 28 November 2008. <http://www.guardian.co.uk/environment/2008/nov/28/china-climate-change> (accessed 30 November 2008).

Yang, Jianxiang. *Worldwatch Institute, China Speeds Up Renewable Energy Development*, 26 October 2006. <http://www.worldwatch.org/node/4691> (accessed 30 November 2008).

End Notes

¹ President, Policy Memorandum, “American Made Energy,” (18 June 2008), <http://www.whitehouse.gov/infocus/energy/energy-policy-memo.pdf>.

² *Energy Independence and Security Act of 2007*, Public Law 110-140, 110th Congress, 1st session, (19 December 2007).

³ President, Policy Memorandum, “American Made Energy.”

⁴ Department of Energy, Energy Info Administration, *2007 U.S. Imports by Country of Origin*, http://tonto.eia.doe.gov/dnav/pet/pet_move_impcus_a2_nus_epc0_im0_mbblpd_a.htm.

⁵ *Ibid.*

⁶ Barack H. Obama, Presidential Remarks, January 26, 2009.

⁷ *Ibid.*

⁸ Travis Bradford, *Solar Revolution: The Economic Transformation of the Global Energy Industry* (Cambridge, MA: The MIT Press, 2006), 89.

⁹ *Ibid.*

¹⁰ National Energy Policy, *Report of the National Energy Policy Development Group* (Washington, DC: U.S. Government Printing Office, May 2001), 5-19.

¹¹ Department of Energy, Energy Information Administration, *Motor Gasoline Retail Prices, U.S. City Averages, Monthly, 1973 – Current*, http://tonto.eia.doe.gov/merquery/mer_data.asp?table=T09.04.

¹² Department of Energy, Energy Information Administration, *Short-Term Energy Outlook, January 13, 2009 Release*, <http://www.eia.doe.gov/emeu/steo/pub/jan09.pdf>.

¹³ John Sheehan et al., *A Look Back at the U.S. Department of Energy’s Aquatic Species Program – Biodiesel from Algae* (Golden, CO: NREL, Jul 1998), 8.

¹⁴ Memorandum of Agreement entitled “Strategic Studies (Blue Horizons) Special Interest Item,” signed by General John D. W. Corley, Vice Chief of Staff of the U.S. Air Force, on May 17, 2006.

¹⁵ *Ibid.*

¹⁶ Volker Quaschning, *Understanding Renewable Energy Systems* (London: Earthscan, 2005), 20.

¹⁷ Travis Bradford, *Solar Revolution: The Economic Transformation of the Global Energy Industry* (Cambridge, MA: The MIT Press, 2006), 90.

¹⁸ *Ibid.*

¹⁹ Vaclav Smil, *General Energetics: Energy in the Biosphere and Civilization* (Hoboken, NJ: Wiley, 1991), 369. http://en.wikipedia.org/wiki/Solar_power.

²⁰ Exergy Flow Chart. http://gcep.stanford.edu/pdfs/GCEP_Exergy_Poster_web.pdf.

²¹ Travis Bradford, *Solar Revolution: The Economic Transformation of the Global Energy Industry*, 90.

²² Nevada Solar One. http://en.wikipedia.org/wiki/Nevada_Solar_One.

²³ Travis Bradford, *Solar Revolution: The Economic Transformation of the Global Energy Industry*, 93.

²⁴ Department of Energy, *Annual Energy Outlook 2008* (Washington DC: US Government Printing Office, June 2008), 177.

²⁵ Department of Energy, *Renewable Energy Data Book* (Washington DC: US Government Printing Office, September 2008), 13.

²⁶ R. M. Dell and D. A. J. Rand, *Clean Energy* (Cambridge, UK: The Royal Society of Chemistry, 2004), 150.

²⁷ Ibid., 153.

²⁸ Department of Defense, *Report to Congress on Energy Security Initiatives, DoD Energy Security Task Force OUSD(AT&L)*, (October 2008), 14.

²⁹ Ibid., 10.

³⁰ Department of Energy, *Annual Energy Outlook 2008*, 177.

³¹ Department of Energy, *Renewable Energy Data Book*, 13.

³² Jay Inslee and Bracken Hendricks, *Apollo's Fire* (Washington, DC: Island Press, 2008), 300-1.

³³ Department of Energy, *Renewable Energy Data Book*, 57.

³⁴ "The Pickins Plan," <http://www.pickinsplan.com/theplan>.

³⁵ Department of Energy, *Annual Energy Outlook 2008*, 177.

³⁶ Department of Energy, *Renewable Energy Data Book*, 58.

³⁷ Department of Energy, *Renewable Energy Data Book*, 13.

³⁸ Jay Inslee and Bracken Hendricks, *Apollo's Fire*, 300.

³⁹ Office of the Director of Defense Research and Engineering, *Report to the Congressional Defense Committee: The Effect of Windmill Farms on Military Readiness*, (2006), 2-3.

⁴⁰ Wim C. Turkenburg (ed), "Renewable Energy Technology," in *World Energy Assessment: Energy and the Challenge of Sustainability* (New York: United Nations Development Program [UNDP], 2000), <http://www.undp.org/seed/eap/activities/wea/index.html>.

⁴¹ National Energy Policy, *Report of the National Energy Policy Development Group*, Glossary.

⁴² Biomass Research and Development Board, *National Biofuels Action Plan* (October 2008), 5.

⁴³ Department of Energy, *U.S. Ethanol Industry: The Next Inflection Point* (Washington DC: US Government Printing Office, August 2008), i.

⁴⁴ Ibid., ii.

⁴⁵ Department of Energy, *Annual Energy Outlook 2008*, 177.

⁴⁶ Department of Energy, *Renewable Energy Data Book*, 13.

⁴⁷ Department of Energy, *U.S. Ethanol Industry: The Next Inflection Point*, introduction.

⁴⁸ Jay Inslee and Bracken Hendricks, *Apollo's Fire*, 301-2.

⁴⁹ John Sheehan et al., *A Look Back at the U.S. Department of Energy's Aquatic Species Program – Biodiesel from Algae*, Executive Summary.

⁵⁰ Ibid.

⁵¹ Ibid.

⁵² Ibid., 2.

⁵³ Ibid., 18.

⁵⁴ Defense Advanced Research Projects Agency (DARPA), *Broad Agency Announcement (BAA) 08-07, Biofuels – Cellulosic and Algal Feedstocks*, <https://www.fbo.gov/utils/view?id=43b32a888ae3a0640e22bc4dfe31b387>, 5.

⁵⁵ Ibid., 7.

⁵⁶ Marsha Walton, *Algae: "The Ultimate in Renewable Energy,"* CNN.com, <http://www.cnn.com/2008/TECH/science/04/01/algae.oil/index.html>.

⁵⁷ International Energy Agency, *World Energy Outlook 2008*, http://www.worldenergyoutlook.org/docs/weo2008/WEO2008_es_english.pdf, executive summary 7.

⁵⁸ International Energy Agency, *World Energy Outlook 2008*, <http://www.worldenergyoutlook.org/quotes.asp>.

⁵⁹ Jianxiang Yang, *Worldwatch Institute, China Speeds Up Renewable Energy Development*, <http://www.worldwatch.org/node/4691>.

⁶⁰ Theodore C. Hailes et al, “Resurgent Russia in 2030: Challenge for the USAF” (Occasional Paper, Air University, July 2008).

⁶¹ Ibid.

⁶² Department of Energy, *Russia: Background*, <http://www.eia.doe.gov/emeu/cabs/Russia/Background.html>.

⁶³ Department of Energy, *International Energy Outlook 2008* (Washington DC: US Government Printing Office, September 2008), 23-57.

⁶⁴ Stratfor Global Intelligence, *The Financial Crisis in Russia*, 28 October 2008, http://www.stratfor.com/analysis/20081024_financial_crisis_russia.

⁶⁵ Rhett A. Butler, *Russia's Folly: An Opportunity for Renewable Energy?*, 3 January 2006, <http://news.mongabay.com/2006/0103-energy.html>.

⁶⁶ Renewables Energy Initiative, *Russia: Country Profile*, <http://www.ebrdrenewables.com/sites/renew/countries/Russia/default.aspx>.

⁶⁷ Ibid.

⁶⁸ Ibid.

⁶⁹ International Energy Agency, *World Energy Outlook 2008*, <http://www.worldenergyoutlook.org/quotes.asp>.

⁷⁰ Global Energy Industry Outlook, <http://www.energybusinessreports.com>.

⁷¹ Jianxiang Yang, *Worldwatch Institute, China Speeds Up Renewable Energy Development*.

⁷² Ibid.

⁷³ Janet L. Sawin, *Worldwatch Institute: Wind Power Continues Rapid Rise*, 9 April 2008, <http://www.worldwatch.org/node/5448>.

⁷⁴ Janet L. Sawin, *Worldwatch Institute: Another Sunny Year for Solar Power*, 8 May 2008, <http://www.worldwatch.org/node/5449>.

⁷⁵ Joe Monfort, *Worldwatch Institute: Despite Obstacles, Biofuels Continue Surge*, 23 April 2008, <http://www.worldwatch.org/node/5450>.

⁷⁶ World Resources Institute: *A 'green lining' in China's economic stimulus plan*, 28 November 2008, <http://www.guardian.co.uk/environment/2008/nov/28/china-climate-change>.

⁷⁷ Ibid.

⁷⁸ International Energy Agency, *World Energy Outlook 2008*, <http://www.worldenergyoutlook.org/quotes.asp>.

⁷⁹ Ibid.

⁸⁰ Department of Energy, *International Energy Outlook 2008*, 32.

⁸¹ United Nations Development Programme Document, <http://web.ng.undp.org/>.

⁸² *Partners in Development: Annual Report 2007*, United Nations Development Programme (UNDP), (Garki, Nigeria: 2008), http://web.ng.undp.org/documents/AnnualReport_2007.pdf, 6.

⁸³ CREN NEWS AND EVENTS, *Nigeria's Renewable Energy Master Plan Launched*, <http://renewablenigeria.org/news.php?newsviewer=0000000021>.

⁸⁴ Colonel James L. Cardoso et al, “Future Insurgency: COIN and the USAF in 2030” (Occasional Paper, Air University, May 2008).

⁸⁵ Ibid.

⁸⁶ S. A. M. Said, I. M. El-Amin and A.M. Al-Shehri, *Renewable Energy Potentials in Saudi Arabia*, King Fahd University of Petroleum & Minerals Dhahran Saudi Arabia, <http://webfea-lbfea.aub.edu.lb/fea/research/erg/RCW/Renewable%20Energy%20Potentials%20in%20Saudi%20Arabia.pdf>.

⁸⁷ RenewableEnergyWorld.com, *Saudi Arabian Plantations to Produce Biodiesel*, 17 February 2005, <http://www.renewableenergyworld.com/rea/news/story?id=22624>.

⁸⁸ International Energy Agency, *World Energy Outlook 2008*, <http://www.worldenergyoutlook.org/quotes.asp>.